2.0 APPROACH

2.1 Background

The reader should be aware that it is not always practical or expedient to make any attempts to protect the environment when explosives must be disposed of. The issue is more of a safety concern at the expense of a temporary loss of environmental quality and a little noise. The choice needs to be made between a safety versus environmental issue: Would you rather protect the public from unexploded ordnance by detonating it and causing a localized and momentary degradation in air quality or would you rather risk lives by transporting an ordnance item to conduct a washout or incineration procedure? The default result usually sides with the safety concern being the overriding issue. With that choice in mind the other options available for destruction and disposal of UXO in TCRA is discussed below.

The very properties that make such waste materials unsuitable for use also increase the risks inherent in their disposal. The sensitivity and high energy of explosives impose unique constraints and limitations on suitable and cost effective handling. Among the conventional methods of disposal of high explosives are open burning and incineration in a variety of specially designed chambers. These are the most widely used procedures that are carried out in remote areas without any controls of gaseous emission products. At this time detonation and open burning are the preferred methods of disposal since these require minimum handling of sensitive materials and allow the materials to be destroyed with the least likelihood of creating an unsafe situation, as might occur in a confining chamber like an incinerator. Incineration which involves the controlled thermal oxidation of sensitive materials in a chamber allows more control of the process and emissions however this route is more expensive in both capital and operating costs, partially because of the special handling requirements and partially because of the control equipment needed to minimize the emissions of the combustion by-products. Emissions similar to open air detonations also result from incinerators, but at concentration which may be higher.

A number of disposal methods are currently available and in use today for explosive wastes. This discussion will be limited to investigating equipment and methods used for disposal and treatment. The most preferred method for disposal of UXO is detonate in place at a designated disposal area very near to the location that the UXO is discovered. The primary reason is the risk involved in transporting unstable munitions items. This transportation is a very dangerous operation which exposes the public to unnecessary risk. Only a few practical disposal methods exist that involve non destructive detonation activity and are currently available for disposal of UXO munitions. These non detonation

disposal activities involve: Popping Furnaces, Washout operations, or dismantling and demilitarization operations.   Much of the non destructive disposal activity involve specialized operations that are usually conducted at permanent facilities. In some cases there may be temporary operations set up to dismantle or demilitarize found munitions at a site. These operations are usually very labor intensive and very hazardous resulting in the possibility explosions near workers. Remote handling facilities also exist however they are usually permanent and very specialized. These are designed to conduct the same procedure over and over on the same type of munitions.

The eventual disposal route for demilitarized munitions are either popping furnaces (destructive) or washout (nondestructive) operations.

All facilities that conduct final treatment operations must be RCRA permitted. Permitting of OB/OD operations are handled under the subpart X provisions of RCRA for miscellaneous units with special provisions for explosive detonation operations. These operations are considered destructive operations.

Non destructive operations involve washout operations. These also require permits under RCRA. The washout operations involve washing the contents of the UXO and handling the wash water or solvent and conducting a treatment process on the contaminated washout solutions.

UXO disposal at the subject sites leaves contamination at the site at levels well below what may be considered hazardous by Federal EPA standards. Airborne fractions of semivolatiles, metals, nitroaromatics, and nitramines are less than what falls out (ejecta and particulates) and is dissipated rapidly by diffusion and winds. Reference 2.1 reports the following calculation for a 907kg (2000 lb) TNT detonation (approximately 10 times the size of the first Camp Claiborne detonation).

- Criterion / restriction for air containing 2,4 dinitrotoluene (DNT) is 15 micrograms per cubic meter ambient air concentration for an 8 hour time period for North Dakota.
- Using an emission factor of 1.05×10^{-6} kg/kg for 2,4 DNT results in 1 gm of material to be dispersed which is assumed as <u>all</u> being dispersed by small particles downwind.
- Using the Volume Source Diffusion Model (VSDM), a peak level of $1ng/m^3$ occurs 2.5km downwind and lasts for a few minutes. This translates to a level 14,000 times less than the most restrictive ambient air standard found (North Dakota).

The largest detonation in this study was at Camp Claiborne at 100 kg or 220 lbs. This is a factor of ~10 less than those tested in the BangBox Series conducted by the U.

S. Army AMCCOM in 1991-1992. With this as a guide, and the fact that specific emission factors for KINEPAC are not available, we have not conducted any air dispersal analyses concluding that levels be well below measurable limits.

2.2   Modeling

2.2.1 Modeling

The range of models and data bases required for this study include:

a.   Dust cloud extent over the immediate area;

b.   Dust cloud loading;

c.   Ejecta extent;

d.   Emissions fractions for potentially hazardous explosion emissions and their distribution in the ejecta and cloud and,

e.   Transport and fallout models

In this section the basis for and the development of the target analytes list is presented. Dust cloud size, shape and loading relations are provided together with limitations and assumptions. Crater and crater ejecta relations are provided. Finally, worse case soil contamination estimates are provided. Comparisons of the various applicable dispersion codes which have the capability of modeling explosively generated inputs (puff vs. continuous injection) are provided in a general sense since their use for these two sites was not deemed necessary.

2.2.2 Semivolatiles

2.2.2.1   Overview of Applicable Tests

A series of closed volume and open air tests have been conducted by U.S. Army Armament, Munitions and Chemical Command (AMCCOM) and the U.S. Air Force Air Combat Command. AMCCOM sponsored controlled volume experiments using a test chamber referred to as the BangBox or BB[2-1] to determine levels of semivolatile organic emissions that result from unconstrained of explosives and propellants in air. A summary of key results is given in cited Reference 2-1 which describes BB test objectives, technical issues, data collection, analysis, quality control, results and conclusions. Explosive charges of 0.5 lb NEW consisting of 2,4,5 - Trinitrotoluene (TNT) were detonated in the BB and products collected and measured. Target analytes consisted of gaseous, volatile and semivolatile organic compounds, unreacted explosive/propellants, regulated metals and non-metals and other potentially detrimental organic compounds. Concentrations were determined by using gas chromatography - mass spectrometry (GC/MS) and supercritical fluid chromatography — mass spectrometry (SFC/MS).

[2-1] BB is owned and operated by Sandia National Laboratories.

These tests were conducted beginning in late 1988. A specific objective of the BB test program was also to develop an alternative, carbon balance, method to estimate initial source strengths of emissions within OB/OD clouds. This method does not depend on knowledge of the field cloud volume.

The second phase of the USA AMCCOM test program consisted of obtaining measurements of semivolatiles from field detonations of 4000 to 10000 lb bulk TNT, composition B, explosive D and RDX at Dugway Proving Grounds (Reference 2.2). These field test phases conducted were: (a) Phase A of initial tests to check out instrumentation and procedures prior to BB testing using approximately 900kg of TNT for each of 7 shots; (b) Phase B to confirm approaches and determine relationship between field test and BB testing using approximately 900k of TNT for each of 13 shots and, (c) Phase C which supplements TNT database with other materials such as approximately 840 to 920 kg of explosive D in each of 7 shots, approximately 880kg of RDX in each of 6 shots, approximately 900kg of composition B in each of 8 shots, along with 10 shots of TNT with NEW of approximately 900kg each.

Sampling for these three phases consisted of fallout sample collection in $1m^2$ pans, collection by aircraft fly through of the dust cloud and selected soil sampling in the crater and ejecta around the craters. Samples of virgin or preshot soil were also taken. Phase A had fallout collection pans located on 50 meter grid intersections; Phase B had 6 pans in each of four rings (50, 100, 150 and 200 meters from the detonation and equally spaced (60°) and phase C had the number of pans per ring reduced to four at 90°.

The U.S. Air Force Air Combat Command sponsored study utilize a range of munitions as well as TNT to quantify emissions produced by open detonation of M384 40mm high explosive cartridges, M18A1 antipersonnel (Claymore) mines, 20mm M56A4 High-Explosive Incendiary cartridges, T45E7 Adapter Booster as well as TNT detonation blocks. All tests were conducted in the BB used in the AMCCOM sponsored tests.

2.2.2.2   BB and Field Test Results

A summary of semivolatiles emission fraction data from the tests described in 2.2.2.1 are shown in Table 2.1 for TNT and Table 2.2 for 20mm HEI rounds detonated in the BB (Reference 2.3). The later is representative of the ordnance found at the Camp Claiborne site. Table 2.3 from Reference 2.3 shows the chemical composition of 20mm HEI rounds. With the exception of explosive rounds containing components not encountered in this study, the analyte list for comp B, RDX, etc. are the same (exceptions are explosives containing picric acid). Significant metals consisted of chromium, nickel,

copper, arsenic (always below detectable limit), lead, cadmium, antimony and barium (no mercury).

We were unable to obtain any emission fraction data for black powder (mortars at Camp Grant) or for the mixture of ammonium nitrate/nitromethane used to detonate the rounds in time for this study.

2.2.2.3 Target Analyte List

A target analyte list for the two sites investigated for this report is shown in Table 2.4 and obtained as follows.

(a) We expected to encounter RDX, TNT, Ammonium nitrate/nitromethane, black powder, miscellaneous explosives in primers, caps, etc.

(b) From the BB series of tests (References 2.1 and 2.2) emissions and emission fractions were available for RDX and TNT.

(c) From the AF series of tests (Reference 2.3), emissions and emission fractions were available for 20 mm HEI rounds expected at Camp Claiborne.

(d) Emissions from ammonium nitrate/nitromethane, black powder and miscellaneous cords and caps were estimated using best judgment of the review team of NRC personnel and SEAS personnel.

The emissions extracted from the BB and AF series of tests are preceded by an "*" in Table 2.4 in bold type. Emission factors for the principle detonation compound used at the two locations (Camp Grant and Camp Claiborne) are not available. Since the explosive weight is larger than the ordnance, emissions calculations for ground contamination using analytical models cannot be performed. Assuming detonation under ideal conditions, calculations of emissions using equilibrium combustion codes can be useful. To obtain estimates of emissions from a mixture of Ammonium Nitrate (oxidizer) and Nitromethane (fuel) explosion, the equilibrium combustion code EQM was utilized. T100 Slurran with the following components and percentages were used.

Oxidizer:	90%	Ammonium Nitrate	
	5%	Sodium Nitrate	77.5%
	5%	Poly Urethane	
Fuel:	100%	Nitromethan	22.5%

This mixture was chosen in that it contains Sodium Nitrate whereas KINEPAC is 100% Ammonium Nitrate. Table 2.5 shows mole fractions of the compounds formed. Also shown are results for mixtures of 60% oxidizer/40% fuel and a 50%/50% mix (which is unlikely). Mixture ratios with higher percentage of oxidizer to fuel will leave

Ammonium Nitrate, Sodium Nitrate unburned. Of interest is the 60/40 and 50/50 mix where low levels of Hydrogen Cyanide gas is apparent. Sodium cyanide is also noticeable in the 50/50 mix. Both gases are highly toxic. Thus, with care to insure the optimum mixture ratio of 77.5% / 22.5% of oxidizer to fuel, a clean burn will occur with N_aOH and $N_{a2}CO_3$ being the only solid constituents which can settle on the surrounding soil.

2.2.3 Cloud Size Shape, Loading Relations

Pans which collect semivolatile bearing particles must be located at radial distances which insure collection of contaminated soil samples. To determine these distances, models for cloud dimensions and ejecta deposition are required. This section outlines these models and the basic assumptions involved.

2.2.3.1   Dust Cloud Dimensions

From Reference 2.4, cloud dimensions at stabilization are given by:

H_T (meters) = Height of Cloud Top = $670W^{0.25}$ 2.1

H_B (meters) = Height of Cloud Bottom = $335W^{0.25}$ 2.2

R_c (meters) = Cloud Radius = $170W^{0.25}$ 2.3

where W is the TNT equivalent explosive weight in tons. The range of application is for explosions of tons to tens of tons. Assuming the cloud to be cylindrical (reasonable assumption from photographic data) and negligible contribution from the dust stem, the cloud volume becomes

$V_c(meters)^3 = 3 \times 10^7 W^{0.5}$ 2.4

These relations apply for depth of burials anticipated for typical remediation where UXOs are collected and detonated with initiator explosives in a pit with backfill. Loading of soil particles in the cloud, crater size and ejecta are impacted by depth of burial and this is addressed below.

Dust clouds from high explosive detonations in the NEW range, referenced above, cease to rise buoyantly within approximately 2 minutes. Subsequent rise is by turbulence and, in most cases, vertical rise ceases 4 to 6 minutes after detonation. At later times, diffusion dominates. Cloud radii demonstrate a tendency to expand very slowly at times corresponding to cloud height stabilization and then continue to increase as diffusion takes hold. From Reference 2.4, the following relations have either been directly obtained or developed from presented data.

a)   at approximately 2 minutes, H_T (meters) = $500W^{0.25}$ 2.5

b)   Stabilization Time = 4 to 5 minutes and will be <u>assumed</u> to apply to our range of interest (fractions of 0.1 ton to 1 ton).

c) $R_c(t) = 4.6t^{0.7524}(W)^{0.25}$ (meters) 2.6

where t is time after burst in seconds for $t \geq 300$ seconds. This relation was derived from data published in Reference 2.4 (missers Bluff II-1) and is assumed to apply to sub-ton range of TNT equivalent yields.

Video and visual observations taken at the Camp Claiborne explosion (115kg NEW) suggest that the cloud does not reach altitudes predicted by these relations. Buoyant forces are smaller and diffusion less so that the cloud rises to approximately 1/2 the height. This is a result of the explosives being spread out in each trench acting more like a sheet of explosive than a concentrated mass and the side venting that occurred (as shown on Video and in Vol II). The radii also appears on video to be smaller but this may be deceiving since fallout pans at 50 meters contained fallout particles. Figure 2.1 a through f show the explosive sequence for this Claiborne detonation. The frame size at the distance of the explosion is 80 meters horizontal and 50 meters vertical.

2.2.3.2   Dust Cloud Loading

From Reference 2.4 the apparent volume of the water is given by

$V_a = V_oWe^{-5.2H(V_oW)^{-1/3}}$, (ft^3) 2.7

where V_o is the cratering efficiency for 0 feet HOB (ft^3/on), W is the TNT equivalent yield in tons and H is the depth above (or below) the ground in feet.

Figure 2.2 from Reference 2.4 shows the variation of apparent crater volume for several soil types.

(a) 0.07 Seconds After Detonation

(b) 0.30 Second After Detonation

(c) 0.67 Seconds After Detonation

(d) 3.0 Seconds After Detonation

(e) 7.2 Seconds After Detonation

(f) 13 Seconds After Detonation
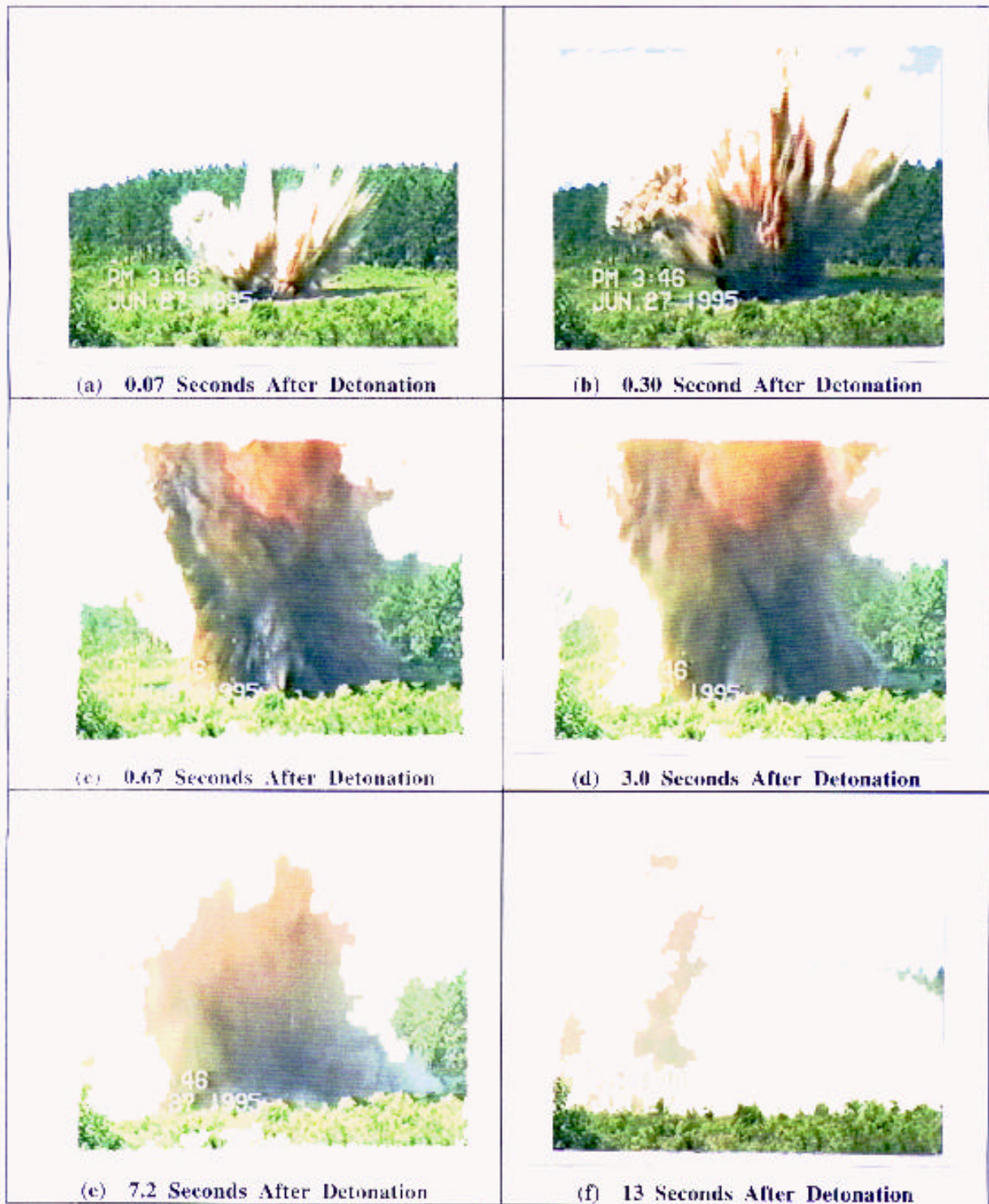
Figure 2.1 Dust and Ejecta Cloud at Early Times
for First Detonation of UXO at Camp Claiborne, Louisiana

V_a = APPARENT CRATER VOLUME (ft^3)

H = HEIGHT-OF-BURST (ft)

V_0 = CRATERING EFFICIENCY AT ZERO HEIGHT-OF-BURST (ft^3/ton)

WET CLAY

WET CLAY/SHALE

WET SAND

WET CORAL SAND/WET CLAY-SHALE

DRY CLAY/DRY SAND

PLAYA

SOFT ROCK

DRY ALLUVIUM

HARD ROCK

MEDIUM	V_0 (ft^3/ton)
WET CLAY	10000
WET SAND	6000
WET CORAL SAND	4000
WET CLAY SHALE	4000
DRY CLAY	1500
DRY SAND	1500
DRY ALLUVIUM	1100
PLAYA	800
DRY SOFT ROCK	700
HARD ROCK	500

V_a/W (ft^3/ton)

10^5 10^4 10^3 10^2 10^1

0.6   0.4   0.2   0   -0.2   -0.4   -0.6

$H/V_a^{1/3}$ (dimensionless)

Figure 2.2 Near-Surface HE Cratering Efficiencies
(From Reference 2.4)

For dry sand, $V_O = 1500$ ft^3. Dry sand weighs 100 lb/ ft^3 so the weight of a one ton surface burst ejecta is $(1500)(100) = 150,000$ lb. From volume 1 of Reference 2.2 (P4.16), the weight of the displaced soil was estimated at 56,000kg or 123,000 lbs — a value in reasonable good agreement with the 150,000 lb. for dry sand.
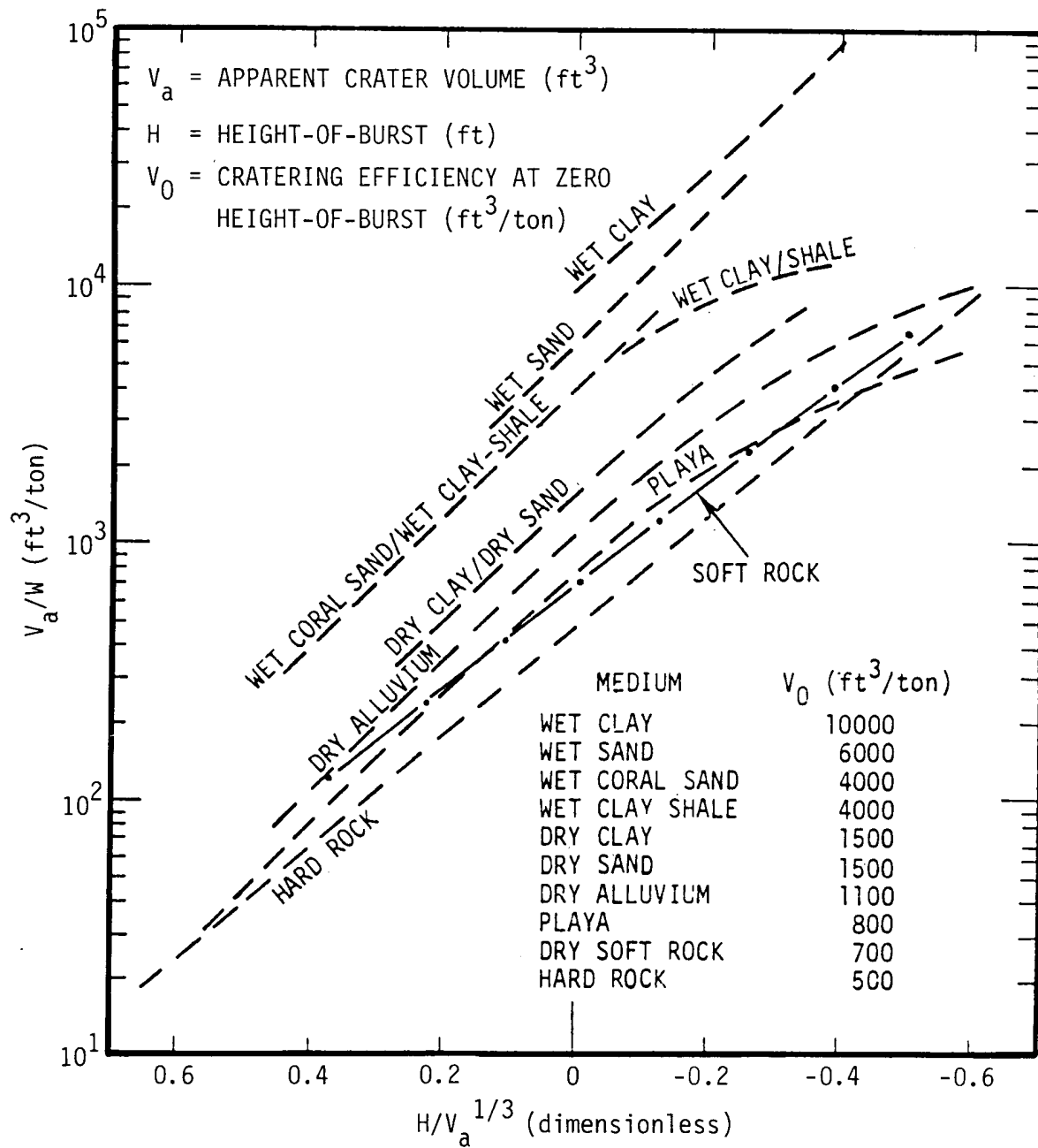
Reference 2.4 indicates that about 1/3 of the mass ejected will reside in the cloud at stabilization. Thus, for 1 ton, 50,000 lb. will be in the cloud and the average density is 4.76×10^{-5} lb/ft^3 or 760mg/m^3. This compares to 840mg/m^3 for Misers Bluff II-1, a 100 ton, well instrumented surface burst (Reference 2.1, p. 38). Peak level measured for 1 ton of TNT from Reference 2.1 is 270 mg/m^3 which suggests that the loading factor at stabilization of 1/3 maybe too high. Limited video coverage of the 115kg detonation at Camp Claiborne suggests that a large fraction of material falls out, therefore the cloud is assumed to contain $\frac{270}{760}$ x 0.33 = 0.20 of the original crater mass. i.e., 80% or larger falls out quickly.

2.2.4 Crater and Crater Ejecta

Figure 2.3 shows the geometry and nomenclature for the crater and the crater ejecta.
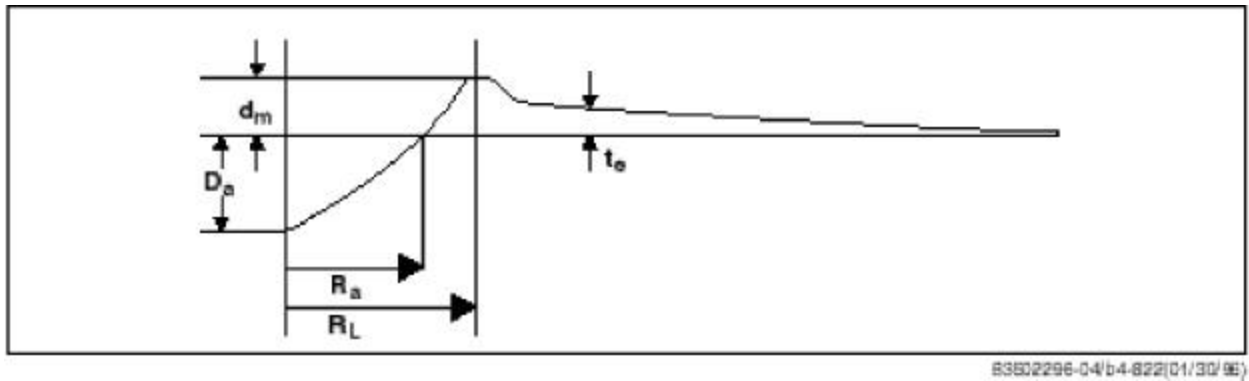
Figure 2.3 Crater and Crater Ejecta Geometry

Key to determining the basic relations is the apparent crater volume as defined and discussed in 2.2.3. The relations are:

$R_a =$	$1.2\ V_a^{1/3}$	2.7
$R_L =$	$1.25\ R_a$	2.8
$D_a =$	$0.5\ V_a^{1/3}$	2.9
$d_m =$	$0.25\ D_a$	2.10

$$t_e = 0.9\, D_a \left(\frac{R_a}{R}\right)^{3.86} \quad \text{for } R > 1.8\, R_a \quad \text{..} \qquad 2.11$$

where dimensions are in consistent units of meter, cm, or feet. The volume of crater ejecta (which also includes fallback) is approximated by the following:

$$V_e = 0.9\, D_a R_a{}^2 = 0.65\, V_a \quad \text{...} \qquad 2.12$$

Thus approximately 2/3 falls out immediately and 1/3 falls out over varying times for a few minutes to hours (for very small particles).

2.2.5 Soil Contamination Estimates

Several codes which predict the dispersion of particulates and gaseous components were reviewed. Table 2.6 summarizes the codes which, with one exception, requires assumptions as to the loading of semivolatiles on particles by size class, non-condensed fractions and detailed knowledge of emissions and quantities. ASL-DUST which was developed by the U.S. Army Electronics Research and Development Command, predicts dust environments for small quantities of explosives such as 155mm shells, C4 up to 20 lbs, etc. These environments were used to determine the impact on radar performance in the battlefield and does not treat loading by contaminants.

With planning for monitoring the open detonations at Camp Claiborne, it became evident that these codes would not be required since approximate, worse case analyses showed that the explosive products would appear in very low concentrations — well below the detection limit used by the assay laboratory. The next site, Camp Grant, would yield even lower concentrations and would be outside the applicability of all but the ASL-DUST code. The conservative approximations applied to predicting the levels of semivolatiles in the fallout (from dust and ejecta) are discussed below:

    a)   all semivolatiles are mixed uniformly with the fraction of particulates which are lofted; namely 1/3 mass represented by V_a (not the 20% discussed above);

    b)   all lofted masses fall out over the area covered by the pans set out to collect this material and any ejecta material (neglects expansion and fallout well beyond the outer pans);

    c)   as an alternative, all semivolatiles are mixed uniformly with the mass ejected and lofted from the crater (mass equivalent of V_a).

Estimates for soil densities in gm/cm^2 of surface area follow.

    a)   From Figure 2.1, V_a for 250 lb or 0.13 tons at 4 feet is 990 ft^3 or 28m^3. This assumes dry clay/dry sand which is consistent with the soil and backfill.

    b)   Semivolatile densities are calculated using the relation

$$\rho_a = \frac{e_a W_e}{f V_a r_s} \quad \text{...} \qquad 2.13$$

where

η_a =   concentration of emissions in g/g_{soil}

ε_a =   emission factor for semivolatile in $g/g_{explosive}$

W_e =   weight of explosive in g

V_a =   Volume of material from crater in g

ρ_s =   soil density in g/cm^3 ~ 1.92 g/cm^3

For the case where 1/3 of $V_a \rho_s$ falls out uniformly over the area bounding the outer collection pans (60 meters),

$$\boldsymbol{h}_a = \frac{\boldsymbol{e}_a W_e}{0.33 V_a \boldsymbol{r}_s} = 5.6 x 10^{-8} \boldsymbol{e}_a W_e$$

and for <u>all</u> soil being uniformly contaminated

$$\boldsymbol{h}_a = 1.7 x 10^{-7} \boldsymbol{e}_a W_e$$

Using the total weight of explosives (115kg or 250 lb), and the largest emission fraction encountered from BangBox experiments of 28µg/g_{exp} for Napthalene yields

$$\boldsymbol{h}_a = (5.6 x 10^{-8})(28 x 10^{-6})(1.15 x 10^5 gm) = 180 \boldsymbol{mg} / kg_{soil})$$

which as highly over estimated as this level of Napthalene is, it is still less than the MDL of 330µg/kg_{soil}) of measurement in the laboratory.

2.3   Sampling Plan

A sampling plan was developed in the early part of the task. The objective of the plan was to ensure that sample collection would be performed in a uniform, repeatable manner and that the samples would not be contaminated or otherwise be compromised. The complete sample collection plan is enclosed in Section 6.

The number, type and location of samples collected was designed to allow the detection and measurement of any soil or waste contamination caused by the open burning/open detonation of the recovered ordnance items and to allow the development of contamination predictions by collecting fallout samples from the detonation(s). As part of the sampling plan, a field logbook was to be kept detailing the specifics of the sample collection and any deviations from the sampling plan. It was also used to record general site observations.

Basically, the intent was to collect background (pre-detonation) samples from the center of the point of detonation, from several points around the perimeter and downwind of the detonation. Prior to the detonation of a shot, aluminum pans were placed in the same areas from which background samples had been collected to catch any fallout from the detonation. After the detonation, samples were to be collected from the crater, from the spoil (ejected materials) around the crater and from the collection pans. Since the

elapsed time was not expected to be sufficient to allow any contaminants to reach subsurface water, no provision was made to collect subsurface samples, however surface water on the site, if any, was to be sampled both pre and post shot.

Because the sampling plan was prepared before seeing the actual disposal areas and in the case of Camp Claiborne, before a disposal site has been selected, the sampling plan was written with sufficient flexibility to allow for changes dictated by the conditions and circumstances of each site. One of the changes which was anticipated was the location of the pans to collect fallout which would have to be positioned based on the net explosive weight of a shot.

Another change which was made subsequent to the post shot sample collection on 27 June 1995 at Camp Claiborne was in the number of samples analyzed. Due to cost constraints, the number of samples to be analyzed was reduced by consolidating portions of several samples. Consolidation was acceptable due to the low variability of concentrations from many collection sites. The composite samples were then analyzed while the individual samples were kept in cold storage. Only if anomalies were found in the composite samples would the individual samples be analyzed. Because of the low concentration levels at Camps Claiborne and Grant, none of the frozen samples have been analyzed.

2.4   Assay of Soil and Water Samples

Southeastern Analytical Services, Inc. of Huntsville, Alabama conducted all laboratory analyses for the analyte target list in Table 2.4. The following methods were used:

(a)   Method SW-846 6010 for metals;

(b)   Method 4110B for Nitrate-Nitrogen;

(c)   USEPA Method SW-846 8270/625 for base/neutral-acid compounds using GC/MS;

(d)   Nitroaromatics and Nitramines by HPLC, USEPA Method SW-846 8330

EPA limits for contamination in soil are site specific and do not exist for Camp Claiborne. For Camp Grant, it has been suggested that the Illinois Background range of metals concentrations measured in counties within the Metro Statistical Areas be used although not directly applicable to Rockford, Illinois. These ranges for metals and one inorganic are give in Table 2.7 (Data obtained from Parsons Engineering).

EPA limits for soil contamination are usually established on a site specific basis as part of a regulated cleanup operation. EPA limits were not specifically established for the Camp Claiborne site.

However, when the background samples and post shot samples are compared to Illinois background ranges all samples at both sites were within or less than background ranges except for barium. However, barium was higher in all background samples at the sites.

There were, however, detection of some contaminants which we believe do not result from the explosion. An occasional sample resulted in very low detection of diburylphthalate and/or bis (2-ethylhexyl)phthalate. These are common laboratory contaminants and sporadic detection of this chemical at very low levels occurs routinely since it is used as a plasticizer in gloves used both in sample collection and testing. In addition to use in plastics used as containers for initiating explosives. Since it appeared sporadically in only a few occasions and not on a regular basis, this chemical should be considered a "laboratory" or sample collection induced contaminant and not an actual site contaminant.

TABLE 2.1 SUMMARY OF EMISSION FACTORS AND SOIL CONCENTRATIONS FOR TNT SEMIVOLATILES

SPECIES	MAXIMUM EF; BANG BOX (µg/g$_{TNT}$)					FIELD TESTS (µg/kg OF SOIL)										
						EJECTA (c) (µg/kg OF SOIL)				FALLOUT-SURFACE BURST (c)					FALLOUT (b) SUSPENDED BURST	
	A '88 (d)	AF LATER SUM.	AF TESTS (a)	AF TESTS (b)	AF TESTS (b)	15 cm CORE A PRE-TEST	A	B,C PRE-TEST	B,C	A	B,C/50	B,C/100	B,C/150	B,C/200	PRE-TEST	POST-TEST
2,6-DINITROTOLUENE	0.439	0.14				0.0027	0.14	9.3(5)	2.3(0.7)	0.14	7.8(0.77)	21(3)	2.1		1.3(0.08)	3.1(0.65)
4-NITROPHENOL	2.59															
2,4,6-TRINITROTOLUENE	1.05	0.17	0.147			0.0012	0.17	1.6(0.33)	8.0(1.3)	0.17	32(4.0)	35(9.2)			9.5(0.62)	13(0.93)
2-NITRONAPHTHALENE	0.643	0.16				0.0029	0.0049	1.6	1.8	0.0026	2.6(0.43)	47(8.7)			0.1(0.04)	1.1(0.12)
2,4,6-TRINITROTOMENE	3.38	0.62	10.2				4.4	24(1.0)	360(23)	0.19	45(13)	310(75)	35(26)	680(110)	1200(33)	1300(25)
1-NITROPYRENE	1.06	BDL	0.0018						1.2							
1,6-DINITROPYRENE	ND															
PHENOL	25.2	9.9	0.337						0.69						3.1(0.65)	1.8(0.55)
DIBENZOFURAN	1.32	0.150	0.029	0.0895				1.6(0.21)	18(0.59)		2.3(0.73)	29(5.2)			0.51(0.22)	31(0.55)
2-NAPHTHYLAMINE	ND															
DIPHENYLAMINE	ND	BDL	0.0176					0.55	0.79			5.4	97(33)	97(24)	0.1(0.023)	0.14(0.057)
BENZ[a]ANTHRALENE	<0.033	BDL						0.39(0.21)	11(1.3)		6.4(1.3)	51(5.6)	1.9	87	1.9(0.29)	4(0.43)
BENZO[a]PYRENE	3.01	0.36										8.5(6.4)	9.1(7.8)			
DIBENZ[a,h]ANTHRALENE	1.73															
N-NITROSADIPHENYLAMINE	1.23	0.20						0.19(0.02)	1.1		0.069				0.3(0.27)	2.8(0.41)
NAPTHALENE	150	28	0.28	0.424			2.3	4.8(0.89)	210(7)	2.4	74(6.0)	220(21)	19(11)	510	27(8.8)	86(13)
1&2 METHYLNAPTHALENE	30			0.907												
1,3,5 TRINITROBENZENE	0.00275	0.00045	1.97				0.24		39(0.97)	0.24	0.89(0.28)	19(5.2)			78(46)	17(0.63)
BIPHENYL	<0.052				0.141											
PHENANTHRENE	0.185			0.0481												
2,5-DIPHENYLOXAZOLE	72.3(?)															
1,1,3-TRIMETHYL-3-PHENYLINDANE	0.57															
PYRENE	0.202	0.032						2.2(0.1)	53(2.4)		36(1.7)	21(4.7)	10	88	2.1(1.1)	7.7(1.7)
RDX			1.37													
HMX			0.061													
ACETOPHENONE				0.177												
BENZYL ALCOHOL				0.208												
BIS (2-ETHYLHEXYL) PHTHALATE				1.19												
BUTYLBENZYLPHTHALATE				0.251												
DIETHYLPHTHALATE				0.24												
DIMETHYLPHTHALATE				0.117												
DI-N-BUTYLPHTHALATE				0.0828												
DI-N-OCTYLPHTHALATE				0.342	0.345											
4-METHYLPHENOL				0.568												
FLUORANTHENE				0.0616												

(a) HI VOL SAMPLED AND ASSAYED USING SFC /MS
(b) HI VOL SAMPLED AND ASSAYED USING EPA METH.8270
(b) PS-1 SAMPLED AND ASSAYED USING EPA METH.8270
(c) NUMBERS IN PARENTHESES ARE AVERAGE OF ALL DETONATIONS IN A PHASE. THE FIRST NUMBER IS THE PEAK ENCOUNTERED
(d) FIRST SET OF TESTS IN BB TO TEST CHAMBER AND INSTRUMENTATION. RESULTS MAY BE CONTAMINATED WITH PRODUCTS OF COMBUSTION FROM PRIOR GANDIA TESTS. USEFULL FOR ANALYTE IDENTIFICATION ONLY.

RDX = HEXAHYDRO-1,3,5 - TRINITRO - 1,3,5 - TRIAZINE
HMX = OCTAHYDRO-1,3,5,7 - TETRANITRO - 1,3,5,7 - TETRAZACINE
ND = NOT DETECTED
(?) = SUSPECT
BDL = BELOW DETECTABLE LIMIT

A - 1988 TESTS ARE SUBJECT TO QUESTION BECAUSE OF BB CONTAMINATION FROM PRIOR USE BY SANDIA. THEY ARE REPRESENTATIVE ONLY.

TABLE 2.2 EMISSION FACTORS FOR SEMIVOLATILES PRODUCED DURING OPEN DETONATION OF 20mm HEI ROUNDS IN THE BB

Analyte	Average, μg / g[1,3]	Average, μg / g[2,3]
2,4 - Dinitrotoluene	0.825	2.4
2-Methylnaphthalene	0.165	
Acenaphthylene	0.128	
Benzyl alcohol	0.0754	
bis (2-Ethylhexyl) phthalate	1.12	
Butyl benzyl phthalate	0.164	
Diethyl phthalate	0.136	
Dimethyl phthalate	0.0620	
Di-n-octyl phthalate	0.950	
Fluorene	0.214	
Naphthalene	0.0925	0.144
N-Nitrosodiethylamine	0.118	
N-Nitrosodiphenylamine	0.134	4.48
Phenanthrene	0.266	
Phenol	0.166	
Pyrene	0.113	0.429
2,6-Dinitrotoluene		0.0717
2,4-Dinitrotoluene		2.41
2-Nitronaphthalene		0.00271
2-Nitrodiphenylamine		0.418
1,3,5-Trinitrobenzene		0.370
N,2,4,6-Tetranitroaniline		0.0207
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)		16.0
Octahydo-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)		1.21
Dibenzofuran		0.0924
Diphenylamine		0.0132
Benz[a]anthracene		0.00432

(1) Tested using EPA GCMS EPA Method SW-846.8270
(2) Tested using SFC/MS (Supercritical Fluid Chromatography/Mass Spectometry)
(3) μg of analyte per gram of explosive in the round
(4) BDL = Below Detection Limits

TABLE 2.3 COMPOSITION OF 20mm HEI ROUND

Ingredient	Weighting
Aluminized RDX	
RDX	6.53
Al Powder	3.74
Wax	.42
Total:	10.69
WC870 Propellant	
Nitrocellulose	30.20
Nitroglycerine	3.72
Diphenylamine	0.90
Dibutyphthalate	2.55
Stannic Dioxide	0.84
Other	0.99
Total:	39.20
I-136 Incendiary	1.29

(1) Graphite, Potassium Nitrate, Sodium Sulphate, Calcium Sulphate, Water, Alcohol and Acetone, each less than 0.5g.

TABLE 2.4 TARGET ANALYTES FOR OPEN DETONATION SITES

a. Base/Netural and Acid Compounds to be Analyzed Using USEPA Method 8270/625

COMPOUND	COMPOUND	COMPOUND
Bis(2-chloroethyl)ether	4-Chlorophenyl phenylether	2-Nitrophenol
1,3-Dichlorobenzene	* Fluorene	2,4-Dimethylphenol
1,2-Dichlorobenzene	Azobenzene	2,4-Dichlorophenol
1,4-Dichlorobenzene	Hexachlorobenzene	4-Chloro-3-Methylphenol
Bis(2-chloroisopropyl)ether	* Phenanthrene	2,4,6-Trichlorophenol
N-Nitrosodi-n-propylamine	Anthracene	2,4-Dinitrophenol
Hexachloroethane	Dibutyl phthalate	* 4-Nitrophenol
Nitrobenzene	* Fluoranthene	2-Methyl-4,6-Dinitrophenol
Isophorone	* Pyrene	Pentachlorophenol
Bis(2-chloroethoxy)methane	* Butylbenzyl phthalate	
1,2,4-Trichlorobenzene	3,3'-Dichlorobenzidine	ADDITIONAL COMPOUNDS:
* Naphthalene	* Benzo(a)anthracene	1-Methylnaphthalene
Hexachlorobutadiene	Chrysene	* Acetophenone
2-Chloronaphthalene	* Bis(2-ethylhexyl)phthalate	* Diphenylamine
* Dimethyl phthalate	* Di-n-octyl phthalate	2-Aminonaphthalene
* 2,6-Dinitrotoluene	Benzo(b)fluoranthene	* 1-Nitropyrene
* Acenaphthylene	Benzo(k)fluoranthene	2,5-Diphenyloxazole
Acenaphthene	* Benzo(a)pyrene	* 2-Nitronaphthalene
* 2,4-Dinitrotoluene	Ideno(1,2,3-cd)pyrene	
* Diethyl phthalate	* Dibenzo(a,h)anthracene	OTHER COMPOUNDS:
Benzidine	Benzo(g,h,i)perylene	* 2 Methylnaphthalene
4-Bromophenyl phenyl ether	* N-Nitrosodiphenylamine	2-&/or 3-Methylphenol
N-nitrosodimethylamine	* Phenol	* 4-Methylphenol
Hexachlorocyclopentadiene	2-Chlorophenol	2,4,5-Trichlorophenol

b. Metals to be Analyzed Using Method 6010

* • Copper	* • Barium	* • Cadmium
* • Lead	* • Nickel	* • Aluminum
* • Chromium	* • Potassium	* • Calcium
• Mercury	* • Zinc	• Titanium

c. Nitroaromatics and Nitramines to be Analyzed Using HPLC USEPA Method 8330

* • HMX	• Nitrobenzene (Surrogate)
* • RDX	* • 2,4,6-Trinitrotoluene
* • 1,3,5-Trinitrobenzine	• 2-AM-Dinitrotoluene
• 1,3 Dinitrobenzine	• 2,4 Dinirotoluene

* - Indicates Commonality to BANGBOX SERIES Lists

TABLE 2.5 EXPLOSIVE PRODUCTS FOR T-100 SLURRAN LIQUID/SOLID AS A FUNCTION OF OXIDIZER/FUEL RATES

COMPOUND	MOLE FRACTION		
	77.5% OX 22.5% FUEL	60% OX 40% FUEL	50% OX 40 % FUEL
CH_3	—	.—	.00001
CH_4	.00000	.00016	.00094
CO	.00229	.07333	.10950
CO_2	.12997	.11168	.10332
H	.00001	.00004	.00005
HNO_2	.00001		
HO_2	.00001		
H_2	.00158	.05183	.07735
H_2O	.59012	.51289	.47083
H_2O_2	.00003		
NH_3	.00002	.00375	.00674
NO	.00076	.00002	.00001
NO_2	.00001		
N_2	.26804	.24120	.22649
N_2O	.00001		
N_aOH (L)	.00000	.00000	.00000
N_aOH	.00089	.00080	.00075
$N_{a2}CO_3$ (1)	.00000	.00000	.00000
$N_{a2}CO_3$ (L)	.00515	.00375	.00301
OH	.00074	.00010	.00007
O_2	.00035		
CH_2O		.00015	.00033
HCN		.00010	.00028
HCO		.00002	.00004
$HNCO$		.00014	.00025
NH_2		.00001	.00001
N_a		.00001	.00001
C (gr)			.00000
N_aCN			.00001
N_aH			.00001

Key: L = Liquid; becomes solid as temperature drops.
1 = Solid
Remainder are gaseous products

TABLE 2.6 PARTICULATE DISPERSION CODES

FEATURES	CODE		
	INPUFF	ASL-DUST	VLSTRACK
POINT SOURCE	√	√	√
LAND USE			
RURAL	√	√	√
URBAN	√		√
RELEASE MODE			
CONTINUOUS	√		
INSTANTANEOUS	√	√	√
CONTAMINATION			
GAS	√		
PARTICULATE	√	√	√
NUMBER OF SOURCES			
SINGLE	√	√	√
MULTIPLE	√		√
COMMENTS	° AIR POLLUTANTS, GASEOUS AND PARTICULATES ° PUFF INPUT	PARTICULATES FROM LOW YIELD HE ROUNDS AND EXPLOSIVES (1-20 kg) DOES NOT HAVE ATTACHED SEMI-VOLATILES. DOES NOT TREAT GASEOUS PRODUCTS	CHEMICAL WARHEAD DISPERSION MODEL. REQUIRES REPLACING CHEMICAL AGENT MODEL WITH POLLUTANTS.

CODES SUCH AS CDM, ISC, MPTER AND CRSTER ARE CONTINUOUS EMISSION CODES WHICH DO NOT CORRECTLY MODEL PUFF INPUTS.

TABLE 2.7 ILLINOIS BACKGROUND RANGE FOR COUNTIES WITHIN THE METROPOLITAN STATISTICAL AREAS.

CATEGORY/METHOD	MATERIAL (1)	RANGE (mg/kg soil)
METALS		
Analyzed by method	* Aluminum	1,388 - 37,200
SW-846-6010	Arsenic	1.1 - 24
	* Barium	D(<0.5) - 1720
	Beryllium	0.059 - 9.9
	* Calcium	813 - 130,000
	* Cadmium	ND(<2.5) - 8.2
	Cobalt	2.1 - 23
	* Chromium	D(<2.14) - 15
	* Copper	D(<2.93) - 15
	Iron	5,000 - 80,000
	* Potassium	270 - 5820
	Magnesium	541 - 74,500
	Manganese	155 - 5,590
	* Nickel	D(<3.1) - 13
	* Lead	4.7 - 647
	Antimony	0.24 - 8
	Selenium	ND(<0.12) - 2.6
	Thallium	0.02 - 1.6
	Vanadium	ND(<2.5) - 80
Analyzed by method	* Zinc	23 - 798
SW-846-7471	* Mercury	0.02 - 0.99
INORGANICS	Cyanide	ND(<.07) - 2.7

Key: "*" Indicates Metals Common with the Study
D =   Detected
ND = Not Detected